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Investigation on Fuzzy Logic and Optimal Fuzzy Logic Controllers Using GA for Multi Area Load Frequency Control with Frequency Controllable HVDC Links

G.Karthikeyan[1] and S.Chandrasekar[2]

[1]Asst. Professor (Sr.G), Department of Electrical and Electronics Engineering, Sona College of Technology, Salem-5, Tamilnadu, India
[2]Principal, Ghanamani College of Engineering, Namakkal, Tamilnadu, India
E-mail: gkarthikeyan_78@yahoo.com, chandrukvt@gmail.com

Abstract

The load–frequency control (LFC) problem has been one of the major subjects in a power system. In practice, LFC systems use proportional–integral (PI) controllers. However since these controllers are designed using a linear model, the non-linearities of the system are not accounted for and they are incapable of gaining good dynamical performance for a wide range of operating conditions in a multi-area power system. This paper focuses on a new optimization technique of a fuzzy logic controller based load frequency controller (LFC) tuned by genetic algorithm (GA) in co-ordination with frequency controllable HVDC links. Conventionally, the membership functions and control rules of fuzzy logic control are obtained by trial and error method are experience of designers. To overcome this problem, the GA tuned FLC is proposed to simultaneously tune the membership functions and control rules of a FLC load frequency controller in order to minimize the frequency deviations of the inter connected power system against load disturbances. The GA introduces additional techniques for improvement of the search process initialization, adaptive search, multiple searches, and crossover and restart process. Simulation results explicitly a show that the performance of the proposed GA tuned FLC is superior to FLC in terms of overshoot and settling time. Furthermore, the robustness of the proposed controller under variations of system parameters and load changes are higher than that of conventional FLC.

Keywords: Optimal Fuzzy Logic, Load Frequency Control, Power System

Control, Genetic Control

Nomenlature

Δ	Deviation from nominal value
P_G	Generated power, pu MW
P_D	Power demand , pu MW
P_C	Speed changer position, pu MW
f	System frequency, Hz
M=2H	Constant of inertia
D	Damping constant
R	Gain of speed drop feedback loop
T_t	Turbine time constant
T_G	Governor time constant
s	Laplace variable

Introduction

Frequency is a major stability criterion for large scale stability in multiple area power system. To provide the stability, active power balance and constant frequency are required. Frequency depends on active power balance. If any changes occur in active power demand or generation in power system, frequency cannot be hold in its rated value. So oscillations increase in both power and frequency. Thus, system subjects to serious instability problems. To improve the stability of the power networks, it is necessary to design a load frequency control system that controls the power generation active power at tie lines. Because of the relationship between active power and frequency, three levels automatic generation controls have proposed by power system researchers [1, 2]. Interconnected power networks with three areas; the generation within each area has to be controlled so as to maintain scheduled power interchange.

In the past several control designs of LFC in interconnected power systems has been studied. The conventional control strategy for the LFC problem is to take the integral of the control error as the conventional signal. An integral (I) controller provides zero steady state frequency deviation but it exhibit poor dynamic performance. Over the past decades, many control strategies for load frequency control of power systems such as linear feedback [4], optimal control [5] and variable structure control [6, 7] have been proposed in order to improve the transient response.

Recently, applications of fuzzy logic theory to the engineering issues have drawn tremendous attention from researchers [13]. The fuzzy logic controller has a number of distinguished advantages over the conventional controllers. It is not so sensitive to the variations of system structure parameters and operation points and can be easily implemented in a large scale non linear system. Furthermore, the fuzzy logic controller is a sophisticated technique that is easy to design and implement Nevertheless, the determination of membership functions and control rules is an inevitable problem in a design. To achieve satisfactory membership functions and control rules, designer's experiences are necessary.

The most straight forward approaches are to define the membership functions and control rules by studying an operating system or an existing controller. Therefore, the effective methods for running the membership function and control rules in order to minimize the output error or maximize the performance index without trial and error method are significantly required.

In the past, the idea of employing the genetic algorithm to solve the combinational optimization problems has been proposed [15-17]. The application of the GA has been used for learning the control rules of the fuzzy logic controller [18], and applied to optimize membership functions and control rules [19].

The contribution of this paper is to propose a new approach based on GA tuned fuzzy logic controller three area load frequency regulation in co-ordination with HVDC links. The HVDC transmission has emerged on a power scenario, due to its numerous technical and economical advantages, for a long chunk of power transfer over large distances. Besides other applications, the commissioning of an HVDC link in parallel with existing ac links has shown beneficial effects from the point of view of stabilization of systems. The proposed controller successfully damps the frequency oscillations and restores the system frequency.

This paper is organized as follows: section 2 illustrates a problem formulation. The implementation of the local robust controller and the models of HVDC and normal tie line models are discussed. The proposed GA tuned fuzzy logic controller is described in section 3. The implementation and simulation results in a three area interconnected power system are offered in section 4. Finally the conclusion is provided in section 5.

Problem Formulation

An N-area power system using reheat type turbines or non heat type turbines is considered. Fig. 1(a) and 1(b) shows isolated single area and the commonly adopted n area model for LFC [1, 5]. Fig. 2(a) shows the three area model is interconnected by two frequency controllable HVDC links and one normal tie line. The model is made more complex by processing area 1 and 2 using reheat type turbines whereas area 3 uses older non-reheat type turbines.

The standard transfer function for a normal tie-line, which shows the incremental power flow from the ith area to the j^{th} area, is provided in fig.2 (a). In considering the frequency controllable HVDC links, it is assumed that the deviation in power system voltage, under the context of LFC, is negligible. Simple first order AFC models, in the form of $\frac{K_{Hij}}{(sT_{Hij}+1)}$, can therefore be used [12]. The transfer functions of the HVDC links, in the presence of AFCs, are given in fig. 2(b) and 2(c). The function of the AFC can be further elaborated by considering fig.2(b) alone, area i will receive almost instantly, an additional power in-flow of $\Delta s_{ij} = \frac{\Delta f_i \times K_{Hij}}{(sT_{Hij}+1)}$ during an additional load demand where both Δf_i and Δs_{ij} are negative; the additional power is obtained from area j.

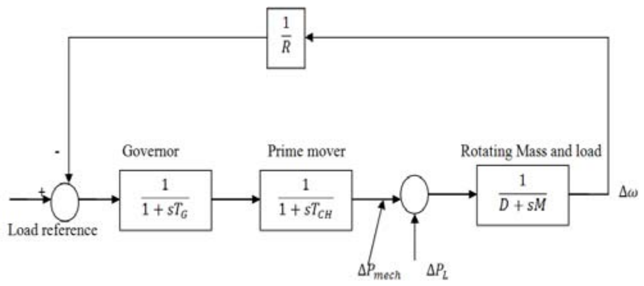

Figure.1(a): Block Diagaram of Single Area islated System

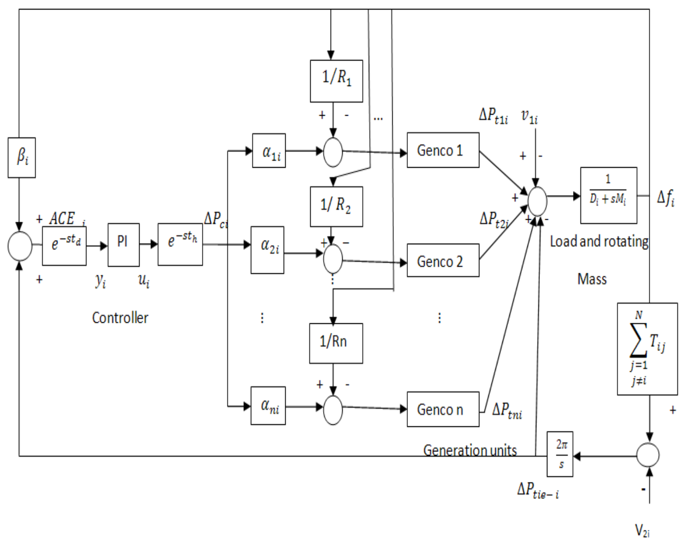

Figure.1(b): Block Diagaram of n Area system with integral Controller

The overall area model, together with its interconnections with other areas, is used for the design of the load frequency controller. A tie-line frequency bias control scheme is normally adopted in each area where the area control error (ACE) has to reach zero asymptotically [1, 5].

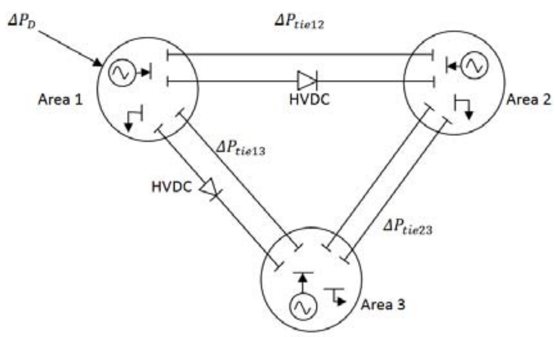

Figure2 (a): Proposed power system Configuration

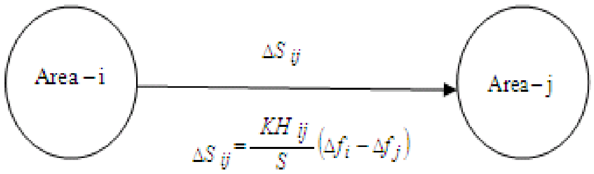

Figure 2(b): Normal tie-Line Model

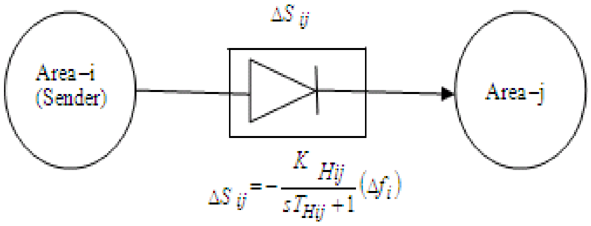

Figure 2(c): Frequency Controllable HVDC tie-line (Receiver)

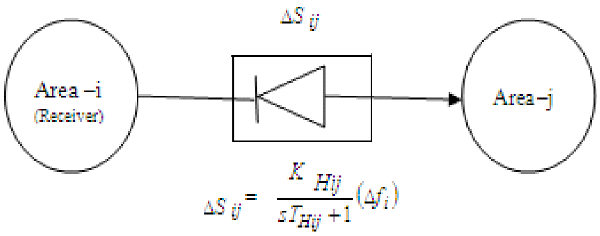

Figure 2(d): Frequency controllable HVDC tie -line (sender)

Equation (1) defines the ACE for the i^{th} area

$$ACE_i(t) = K_{Bi}\Delta f_i(t) + \Delta s_i(t) \qquad (1)$$

The ACEs of equation (1) are being imposed and regulated in areas 1 and 2 of our proposed model; area 3 is assigned to perform mere frequency regulation which means $ACE_2(t)$ has no $\Delta s_2(t)$ term. Such an arrangement makes the problem formulation more interesting and is permissible because the other two areas will be regulating the power flow in and out of area 2. Reference [1] has suggested neglecting time constants that are lower than a few seconds because LFC is a slow process. T_{Qi}, $T_{Ti}$and T_{Hi} are typically much lower than one second (1). Equation (2) is hence derived, with omission of T_{Qi} andT_{Ti}, for areas using reheats type turbines (i.e. Area 1 and 2).

$$\Delta P_{gi}(t) = -\frac{C1}{Ri}\Delta f_i(t) - C_i\Delta E_i(t) + C_i u_i(t) + \Delta Pgi(t) \qquad (2)$$

Where,

$$\Delta\hat{P}_{gi} = (1 - C_i)/(sT_{Ri} + 1)[-\frac{\Delta fi(t)}{R_i} - \Delta E_i(t) + u_i(t)] \quad (3)$$

It should be noted that is difficult to measure and parameters line R_i and T_{Ri} are not fixed in real operation. $\Delta\hat{P}_{gi}(t)$ is therefore rendered as an immeasurable state in our controller design exercise. A technique is developed to tune the corresponding feedback gain to zero so that measurement of is not required. The proposed system contains different area models, transmission lines (10 other areas) and frequency regulation schemes. It can be deuced that the mathematical descriptions for one area are different from another. The matrices for the three models as derived from fig. (1) and (2) and equations (1) and (3) are given in equations (4)-(6). It should be noted that these are the overall area descriptions where the presence of the AFCs has been considered.

Area 1 (using reheats type turbines)

$$\dot{X}_1(t) = A_1x_1(t) + B_1u_1(t) + \sum_{J=2,3} Gi, j\, xj(t) + F1Pd1(t) \quad (4)$$

Where,

$x_1(t) = (\Delta f_1(t) \quad \Delta\hat{P}_{g1}(t) \quad \Delta E_1(t))$

$X_1(t)$ are defined in their respective areas

$$A_1 = \begin{pmatrix} -c\frac{\left(\frac{C1KP1}{R1}\right)+1}{T_{P1}} & K_{P1}/T_{P1} & -C_1K_{P1}/T_{P1} \\ -(1-C_1)/R_1T_{R1} & -1/T_{R1} & -(1-C_1)/T_{R1} \\ K_{E1}/K_{B1} & 0 & 0 \end{pmatrix}$$

$B_1 = (C_1K_{P1}/T_{P1} \quad (1-C_1)/T_{R1} \quad 0)$

$$G_{12} = \begin{pmatrix} K_{H12}K_{P1}/T_{P1} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ K_{H12}K_{E1} & 0 & 0 & 0 \end{pmatrix}$$

$$G_{13} = \begin{pmatrix} K_{H13}K_{P1} & 0 \\ 0 & 0 \\ K_{H13}K_{E1} & 0 \end{pmatrix}$$

$F_1 = (-\frac{K_{P1}}{T_{P1}} \quad 0 \quad 0)^T$

Area 2 (using reheat type turbines)

$$\dot{X}_2(t) = A_2x_2(t) + B_2u_2(t) + G_{23}x_3(t) + F_2\Delta P_{22}(t) \quad (5)$$

Where,

$x_2(t) = (\Delta f_2(t) \quad \Delta\hat{P}_{g2}(t) \quad \Delta E_2(t) \quad \Delta S_{23}(t))$

$X_3(t)$ will be defined in area (3)

$$A_2 = \begin{pmatrix} \frac{-(C_2K_{P2})}{R_2} + K_{H12}K_{P2} + 1 & \frac{K_{P2}}{T_{P2}} & -\frac{C_2K_{P2}}{T_{P2}} & \frac{-K_{P2}}{T_{P2}} \\ -\frac{1-C_1}{T_{R2}R_2} & -\frac{1}{T_{R2}} & -\frac{1-C_2}{T_{R2}} & 0 \\ K_{E2}(K_{B2}+K_{H12}) & 0 & 0 & K_{E2} \\ K_{H23} & 0 & 0 & 0 \end{pmatrix}$$

$$B_2 = (-K_{P2}C_2/T_{P2} \quad (1-C_2)/T_{R2} \quad 0 \quad 0)$$

$$G_{23} = \begin{pmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ -K_{H23} & 0 \end{pmatrix}$$

$$F_{23} = (-K_{P2}/T_{P2} \quad 0 \quad 0 \quad 0)^T$$

Area 3 (using non reheat type turbines):

$$\dot{X}_3(t) = A_3x_3(t) + B_3u_3(t) + G_{32}x_2(t) + F_3\Delta P_{33}(t) \qquad (6)$$

Where,

$x_3(t) = (\ \Delta f_3(t) \quad \Delta\hat{E}_3(t)\ )$

$\Delta\hat{E}_3(t) = \Delta E_3(t) + \Delta S_{32}(t)$

$X_2(t)$ was defined in area 2

$$A_3 = \begin{pmatrix} (\frac{(K_{P3})}{R_3} + K_{H13}K_{P3} + 1)/T_{P3} & -K_{P3}/T_{P3} \\ K_{E3}+K_{A32} & 0 \end{pmatrix}$$

$$B_3 = (\ K_{P3}/T_{P3} \quad 0)^T$$

$$G_{32} = \begin{pmatrix} 0 & 0 & 0 & 0 \\ -K_{A32} & 0 & 0 & 0 \end{pmatrix}$$

$$F_2 = (-K_{P3}/T_{P3} \quad 0\ )^T$$

The Different types of areas, however can generally be described as follows,

$$\dot{X}_i(t) = A_ix_i(t) + B_iu_i(t) + \sum_{J \in N} G_{ij}x_j(t) + F_i\Delta P_{di}(t)$$

Where G_{ij} is zero where there is no connection between j^{th} and i^{th} areas or in case where the i^{th} area is receiving HVDC from the j^{th} area via an AFC (eg. G_{21} and G_{31}).

Optimal Fuzzy Logic Based Controller Design

Nowadays fuzzy logic is used in almost all sectors of industry and science. One of them is power system control. Fuzzy logic control is one of the most successful areas in the application of fuzzy theory. Fuzzy logic controls are excellent alternatives to the conventional control methodology when the processes are too complex for analysis by conventional mathematical techniques [15]. Because of the complexity and multi-variable conditions of the power system, conventional control methods may not give satisfactory solutions. On the other hand, their robustness and reliability make fuzzy controllers useful for solving a wide range of control problems in the power systems. Components of fuzzy logic controller are shown in figure 3 and it consists of four components: a fuzzifier, an inference engine, a defuzzifier and knowledge base.

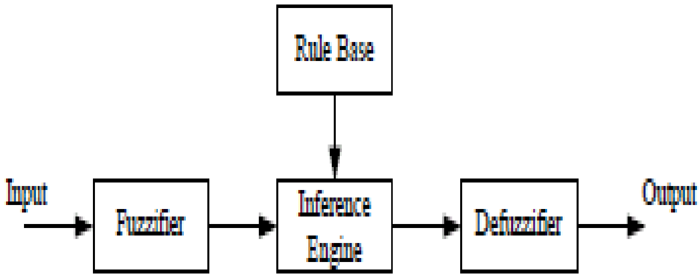

Figure 3: Components of a Fuzzy Logic Controller

In this paper, the Mamdani's min-max operator in inferencing and center of gravity as the defuzzification are used. In the proposed strategy, the conventional controller for LFC scheme (Fig. 1.b) is replaced by a Fuzzy Logic controller tuned by GA. The K_{Pi}, K_{Ii} and K_{di} gains in (7) are tuned on-line in terms of the knowledge base and fuzzy inference, and then, the conventional PID controller generates the control signal. The motivation of using the fuzzy logic for tuning parameters of PID controllers is to take large parametric uncertainties, system nonlinearities into account and minimize the area load disturbances.

$$u_i = K_{Pi}\,ACE_i + K_{Ii}\int_0^t ACE_i\,dt + K_{di}\,ACE_i dt \qquad (7)$$

The parameters, K_{Ii}, K_{di} and K_{pi} are determined by a set of fuzzy rules of the form:
If ACE_i is A_i and ΔACE_i is B_i then K_{di} is C_i and K_{pi} is D_i and K_{Ii} is E_i, i=1,2, ,n. (8)

Where, A_i, B_i, C_i, D_i and E_i are fuzzy sets on the corresponding supporting sets. Fuzzy logic shows experience and preference through its membership functions. These functions have different shapes depending on the system expert's experience. The membership function (*MF*) sets for *ACEi*, ΔACE_i are shown in Fig. 4. In which *NB, NS, Z, PS, PB* represent Negative Big, Negative Small, Zero, Positive Big, Positive Small, respectively.

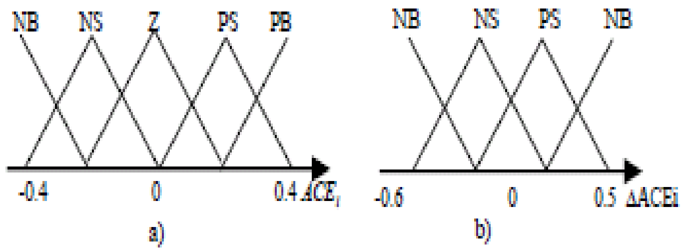

Figure 4(a): Membership for ACE_i b) Membership for ΔACE_i

GA's are search algorithms based on the mechanism of natural selection and natural genetics. They can be considered as a general-purpose optimization method and have been successfully applied to search and optimization [16]. In the GA just like natural genetics a chromosomes (a string) will contain some genes. These binary bits are suitably decoded to represent the character of the string. A population size is chosen consisting of several parent strings. The strings are then subjected to evaluation of fitness function. The strings with more fitness function will only survive for the next generation, in the process of the selection and copying, the string with less fitness function will die. The former strings now produce new off-springs by crossover and some off-springs undergo mutation operation depending upend mutation probability to avoid premature convergence to suboptimal condition. In this way, a new population different from the old one is formed in each genetic iteration cycle. The whole process is repeated for several iteration cycles utill the fitness function of an offspring is reach to the maximum value. Thus, that string is the required optimal solution.

For our optimization problem, the new following fitness function is proposed:

$$f = \frac{1}{1 + \mathrm{MSE(Performance\ Index)}}$$

Where,

$$\mathrm{MSE(Performance\ Index)} = \frac{\sqrt{\sum_{i=1}^{3} 100 \int_0^1 t|\mathrm{ACE_i}|dt}}{3}$$

A string of 180 binary bits reprints gains of PID controller in three areas, population size and maximum generation are 20 and 100, respectively.

The least MSE is the better string. The better string survives in the next population. Based on the roulette wheel, some strings are selected to make the next population. After the selection and copying the usual mutual crossover of the string (crossover probability is chosen 97%) and mutation of some of the string (mutation probability is chosen 8%) are performed. In this way, new offspring of rule sets are produced in the total population then system performance characteristics and corresponding fitness value are recomputed for each string. Thus, the sequential process of fitness function, selection, crossover, mutation evaluation completes genetic iteration cycle.

The experimental study will be focused on applying different tuning processes to a simple fuzzy model previously generated. The well-known Wang and Mendel (WM) method [4] will be used to derive initial rule bases. Therefore, the WM method will act as the learning module shown in Fig. 5

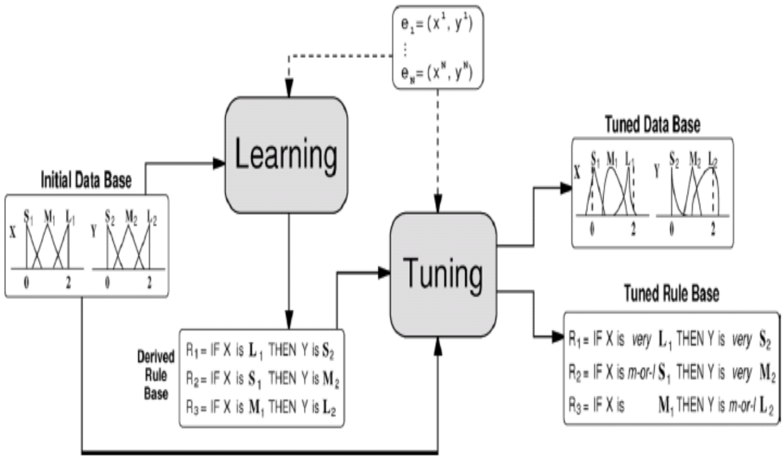

Figure 5: Tuning process of Fuzzy Rules

Where the two-stage tuning operation mode considered in this experimental study is graphically shown. This learning method was selected thanks to some interesting advantages that become a significant importance in our two stage design approach. The fuzzy rule base is listed in Tables 1.

Table 1: Fuzzy Rule Table

		ΔACE$_i$			
		NB	NS	PS	PB
ACE$_i$	NB	NS	PS	NB	NB
	NS	PB	NM	Z	NM
	Z	NB	PB	NS	PM
	PS	PB	PM	NB	PB
	PB	NB	NS	NB	NM

Simulation Results

In this section of paper we present analysis the simulation results of the test system consists of three areas. As mentioned before, the first two areas uses reheat type turbines and the last one uses non-reheat type turbines. Area 1 assists in the frequency regulation for Areas 2 and 3 via HVDC links with AFCs. Areas 2 and 3 are connected with a normal tie-line. The area parameters are given in table- 2.

Table 2: Plant Parameters and Constants

Parameters	**Area-1**	**Area-2**	**Area-3**
Turbine time constant	0.5 s	0.6 s	0.5 s
Generator Time constant	0.2s	0.3s	0.2s
Generator Angular Momentum	10MJrad/s	8 MJrad/s	10MJrad/s
Governor Speed Regulation	0.05 p.u	0.065 p.u	0.05 p.u
Load change for Frequency change of 1%	0.6%	0.9%	0.6%
D = Δp / Δf	0.6	0.9	0.6
Rated output	250 MW	250 MW	250 MW
Sudden Load Variation	1 p.u	1 p.u	1 p.u

Case: 1
All the three areas are nominal parameters

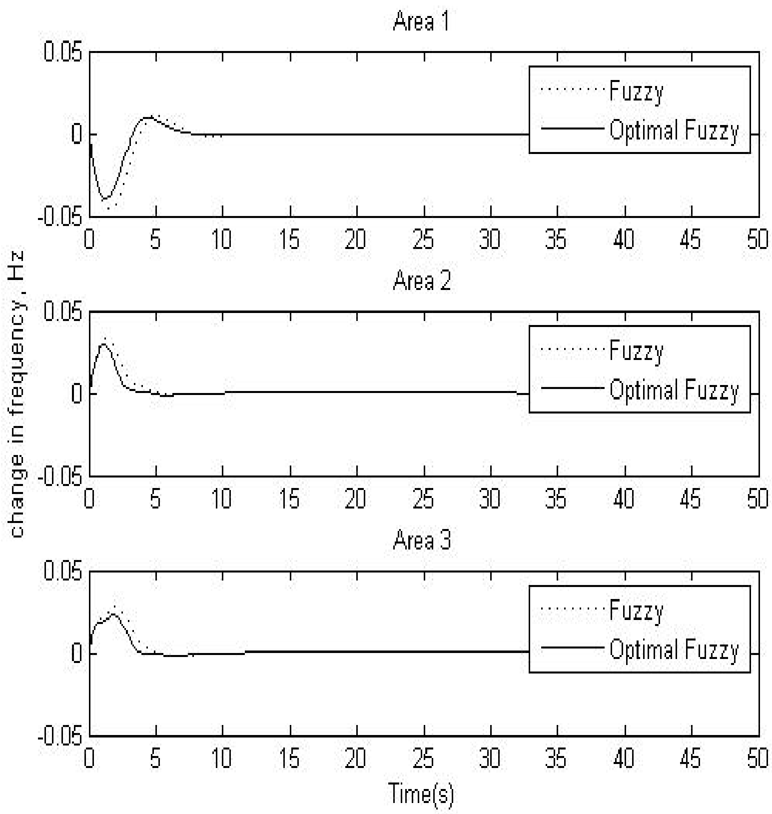

Figure 6: The Deviations of Δf with Fuzzy and optimal Fuzzy for nominal parameters

Case: 2
All the three areas are 20% lower than nominal parameters.

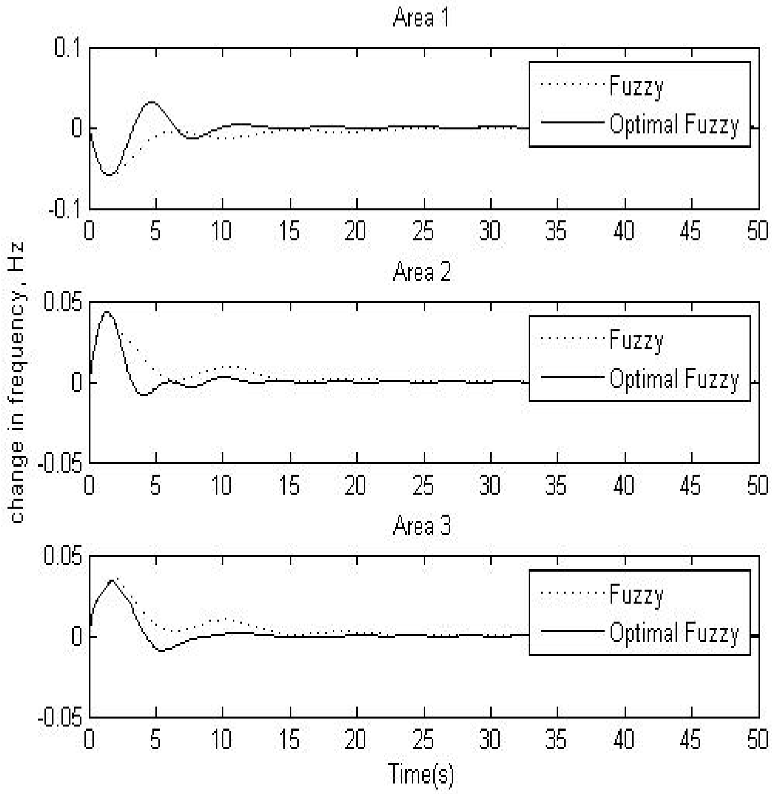

Figure.7: The Deviations of Δf with Fuzzy and optimal Fuzzy for 20% lower parameters

Case: 3
All the three areas are 20% Higher than nominal parameters

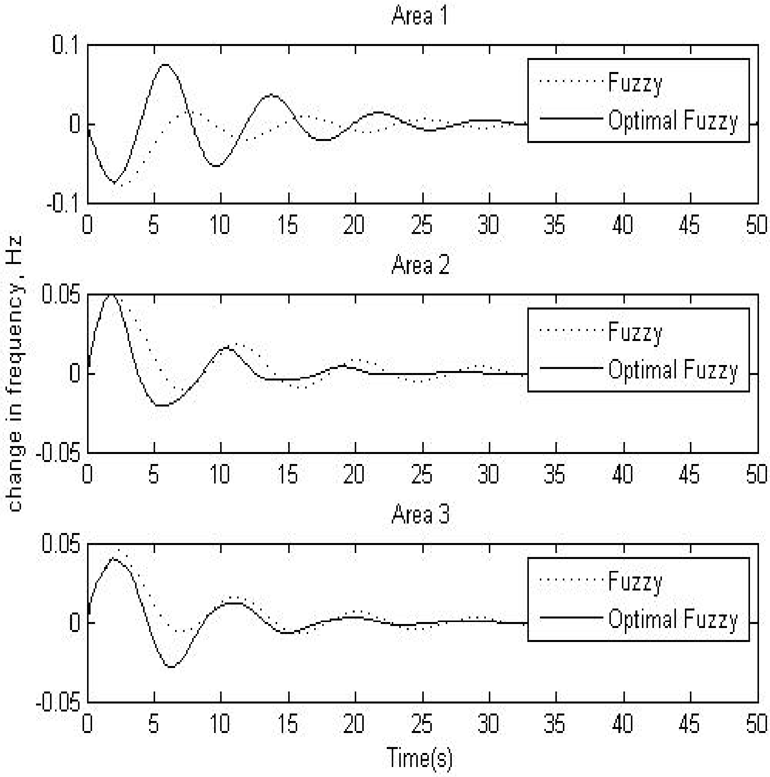

Figure 8: The Deviations of Δf with Fuzzy and optimal Fuzzy for 20% higher parameters

From the response of the figure 6, 7 and 8 of area 1 to area 3 we can conclude that the GA tuned Fuzzy Logic Controller yields better Performance than the Conventional Fuzzy Logic Controller, since the GA tuned Fuzzy Logic Controller gives less undershoot and less settling time of all the areas. The quantitative comparisons for case- 1, 2 and 3 are given in table - 3.

Table 3: Quantitative Comparisons for Case- 1, 2 and 3

Case- 1: All the three areas are nominal parameters.				
Dyanamic responses	**Peak under shoot (Hz)**		**Settling Time (Sec)**	
Controller	Fuzzy	Optimal Fuzzy	Fuzzy	Optimal Fuzzy
Area 1	-0.0397	-0.0283	12.5	7.55
Arae 2	0.0392	0.02864	10.38	6.505
Area 3	0.02792	0.02244	13.59	7.58

Case- 2: All the three Areas are 20% Lower than Nominal Parameters				
Area 1	-0.00934	0.03033	17.68	13.2
Arae 2	0.04516	0.04382	23.95	13.4
Area 3	0.03656	0.03481	22.45	13.75
Case- 3: All the three Areas are 20% Higher than Nominal Parameters				
Area 1	0.4202	0.4267	14.57	2.13
Arae 2	0.04911	0.05272	> 50	48.9
Area 3	0.05113	0.04361	> 50	49.6

With reference of the above table.3, We can conclude that the Peak under shoot and settling time should be minimum of the optimal fuzzy logic controller compared the other type of controllers.

Conclusion

A new method for the LFC, using GA based on Fuzzy optimization has been proposed for a large-scale power system. The proposed method was applied to a three-control area power system and was tested with different load change scenarios. The contribution of this work has been the application of GA tuned fuzzy Controller based Load Frequency Control in co-ordination with frequency controllable HVDC links for a three area system. Use of HVDC links in the system reduces long distance transmission cost and power loss. The time-domain simulation results show that the proposed optimal fuzzy logic controller can provide good damping to each power area and reduce the overshoot compared with conventional fuzzy logic controller. The GA tuned fuzzy logic approach yields automatic, self adjusting outputs irrespective of widely varying, imprecise uncertain off-nominal conditions. Hence optimal fuzzy logic controller has large potential to be used as a control strategy for the Load Frequency Control.

References

[1] N.Jaleeli,L.S.V anslyk,D.N.Ewart,L.H.Fink, and A.G.Hoffmann, 1992. ”Understanding Automatic Generation Control,” *IEEE Trans. On Power Systems*, vol. 7, no. 3, pp. 1106-1112.

[2] C.S.Chang and F.Weihui, 1997. “Area Load Frequency Control Using Fuzzy Gain Scheduling of PI Controllers,” *Electr. Power Syst. Res.*, vol. 42, pp. 145-152.

[3] J.A.Blandand and G. P. Dawson, 1991. “Tabu Search and Design Optimization” *Computer-Aided Design*, vol. 23, no. 3, pp. 195-201.

[4] O.P.Malik, A. Kumar, and G. S. Hope, 1988. "A Load Frequency Control Algorithm based on a Generalized Approach," *IEEE Trans. Power Systems.*, vol. 3, no. 2, pp. 375-382.

[5] N.Saha and S. P. Ghoshal, 1986. "State Adaptive Optimal Generation Control of Energy Systems," *JIEEE, vol 6,* Part EL -2.

[6] A.Kumar, O. P. Malik, and G. S. Hope, 1985. "Variable Structure-System Control Applied to AGC of an Interconnected Power System," *IEE Proc. 132*, Part C, no. 1, pp. 23-29.

[7] Z.M.Ai-Hamouz and Y. L. Abdel-Magid, 1993. "Variable Structure Load-Frequency Controllers for Multi Area Power Systems," *Int. J. Electr. Power Energ. Syst.*, vol. 15, no. 5, pp. 23-29.

[8] C.T.Pan and C. M. Liaw, 1989. "An Adaptive Control using Fuzzy Logic," *IEEE Trans. on Power Systems*, vol. 4, no. 1, pp. 122-128.

[9] C.S.Indulkar and B. Raj, 1995. "Application of Fuzzy Controller to Automatic Generation Control," *Electric Mach. Power Systems*, vol. 23, no. 2, pp. 209-220.

[10] D.K.Chaturvedi, P. S. Satsangi, and P. K. Kalra, , 1999. "Load frequency control: A Generalized Neural Network Approach," *Electrical Power and Energy Systems*, vol. 21, pp. 405-415.

[11] A.Hariri and O. P. Malik, 1999. "Fuzzy Logic Power System Stabilizer Based on Genetically Optimized Adaptive Network," *Fuzzy Sets Systems*, vol. 102, pp. 31-40.

[12] C.Ertugrul and I. Kocaarslan, , 2005. "A Fuzzy Gain Scheduling PI Controller Application for an Interconnected Electrical Power System," *Electr. Power Syst. Res.,* vol. 73, pp. 267-274.

[13] M.E.El-Hawary, 1998. *Electric Power Applications of Fuzzy Systems*, IEEE Press, New York.

[14] H.Shayeghi,H.A. Shayanfar,2005. "Decentralized Load Frequency Control of a Restructured Electric Power System Using ANN Technique", WSEAS *Trans. on Systems and Circuits*, 38–47.

[15] F.Glover, 1989. "Tabu Search Part I," ORSA *J. Comput*., vol. 1, no. 3, pp. 190-206.

[16] S.Ghoshal , 2003." Application of GA Based Optimal Integral Gain in Fuzzy Based Active Power Frequency Control of Non- Reheat and Reheat Thermal Generating Systems", *J. Elect. Power systems Research,* 67.

[17] J.Talaq and F. AL-Basri, 1999. "Adaptive Fuzzy Gain Scheduling for Load Frequency Control," *IEEE Trans. on Power Systems*, vol. 14, no. 1, pp. 145-150.

[18] M.Denna, G. Mauri, and A. M. Zanaboni, , 1999. "Learning Fuzzy Rules with Tabu Search-an Application to Control," *IEEE Trans. on Fuzzy Systems*, vol. 7, pp. 295-318.

[19] D.Karaboga, 1996. "Design of Fuzzy Logic Controllers using Tabu Search Algorithm," *Fuzzy Information Processing Society, NAFIPS, 1996 Biennial Conference of the North American*, pp. 489-491.

[20] C.C.Lee, 1990. "Fuzzy Logic in Control Systems: Fuzzy Logic Controller, parts I-II.," *IEEE Trans. Syst. Man Cyber*, vol. 20, no. 2, pp. 404-418.

Authors

G.Karthikeyan was born in India, in 1978. He is received the B.E. degree in electrical and electronics engineering from Mailam Engineering college, Mailam in 2003 and M.E. degree in power systems engineering from Sona college of Technology, Salem in India, in 2006. Currently he is working as Asst. Professor (Sr.G) at Sona college of Technology in the department of Electrical and Electronics Engineering. His areas of research interest are power system automation and artificial intelligence techniques applications in electric power engineering.

Dr. S. Chandrasekar was born in India, in 1975. He received the B.E. degree in electrical and electronics engineering from Thiagarajar College Engineering Madurai in 1996 and the M.E degree in power system engineering from Coimbatore Institute of Technology, Coimbatore in India in 2001 and the Ph.D. degree from the Indian Institute of Technology Madras, India in 2005. He was a postdoctoral research fellow at the University of Bologna, Italy from 2005 to 2006. Currently, he is working as a Principal at Ghanamani College of Engineering. His research interests include condition monitoring of power apparatus and systems, insulation engineering, signal processing and artificial intelligence techniques applications in electric power engineering.